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UNITED STATES
DEPARTMENT OF THE INTERIOR
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MINING AND MILLING METHODS AND COSTS AT THE ASH PEAK MINE OF THE VETA MINES, INC., DUNCAN, ARIZ.

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HERBERT L. LINES

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MINING AND MILLING METHODS AND COSTS AT THE ASH PEAK MINE OF THE VETA MINES, INC., DUNCAN, ARIZ.[1]

By Herbert L. Lines[2]

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7119."

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INTRODUCTION

This paper is one of a series on mining and milling methods and costs published by the Bureau of Mines.

The Ash Peak mine of the Veta Mines, Inc., Duncan, Ariz., is of particular interest in that the only metal of commercial value in the ore is silver. The silver is concentrated by flotation; the concentrate is shipped to a smelter for treatment.

ACKNOWLEDGMENTS

The writer is especially indebted to R. H. Sayre, president and gener manager of Veta Mines, Inc., through whose courtesy this paper was made possible. Grateful acknowledgment is also extended to Harry E. Davis, mine superintendent, and Ralph Shiminin, mill superintendent, who kindly supplied details of operation. M. E. Volin, assistant engineer of the Bureau of Mines, assisted in preparing the paper.

SITUATION AND ACCESSIBILITY

The Ash Peak mine and mill are at the foot of Ash Peak in the Ash Peak mining district, Greenlee County, southeastern Arizona; it is 12 miles west of Duncan, a station on the Arizona & New Mexico Railroad, a subsidiary of the Southern Pacific Railroad running from Lordsburg, N. M., to Morenci, Ariz. Paved highway 70 goes through Duncan and passes within 1 mile of the mine, which is reached from the highway by a dirt road with an average 12-percent grade.

CLIMATE

Duncan has climatic conditions similar to those at the Ash Peak mine. According to the Weather Bureau,[3] the average daily temperature at Duncan over a period of 23 years was 65.9°, with a low average daily temperature of 44.5° in December and a high average of 85.2° in July. The lowest temperature recorded in 6 years was 4° in January and the highest temperature in the same period 112° in July.

The average annual precipitation in 8 years was 11.17 inches. The greatest average amount was 1.86 inches in August and the least, 0.25 inch in May.

The altitude of Duncan is 3,645 feet and at the mine 4,200 feet.

HISTORY

The early history of the Ash Peak mine is not known to the writer. According to a geological report made by Grant[4] in 1918, Goldfield Consolidated Mines Co. held an option on five lode claims and two millsites for which an application for patent had been made.

Development by the Goldfield company in 1918 and 1919 comprised an 800-foot shaft, the Shamrock; a 500-foot shaft, the Commerce; 110 feet of shallow shafts; and 6,167 feet of drifts and raises. Improvements to the property comprised roads, a water-supply system with its source at Ash Springs, living quarters, office and store buildings, and buildings for housing the mining equipment that was installed to develop the property.

The Veta Mines, Inc., took over the property in 1936 in substantially the condition described and commenced stoping in March 1937. There is no record of any silver concentrates being produced by milling ore from the Ash Peak mine until the present company began operations.

GEOLOGY

There are no sedimentary rocks in the vicinity of the Ash Peak mine except a little Gila conglomerate and recent wash. According to Grant, the formation consists of a series of surface flows and tuffs which have gentle southerly dips ranging up to 10°. There are also numerous dikes and volcanic plugs.

The Ash Peak vein occurs along a strong fault fissure of considerable displacement which shears the tertiary tuffs and flows of rhyolite and andesite; it is continuous for over 2 miles, forming hogbacks in places.

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[3] Weather Bureau, Climatic Summary of the United States, Section 26, Southern Arizona: Pp. 11, 22-24.

[4] Grant, Wilbur H., Geological Report on the Ash Peak Mine, Duncan, Greenlee County, Ariz.: November-December, 1918.

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The vein strikes N. 60° W. and dips 80° N. Vein matter occupies the footwall side of the fissure.

A diabase dike, which possibly was a feeder to basalt surface flows now eroded away, separates the vein matter from the hanging wall of the fissure. This feature presents a complication in that the diabase sloughs and fractures easily, making it difficult to mine the ore clean.

The ore ranges from 3 to 18 feet in width, averaging 7 feet. It decreases in grade from the dike toward the footwall. Typical Ash Peak ore is made up of abundant dense banded chalcedonic quartz and a silicifie andesite showing some flow structure, varying amounts of calcite, rhodochrosite, and pyrite, and small amounts of silver occurring as clouds of fine argentite or as streaks associated with the quartz, evidenced by thei unusual hardness. The argentite is readily recognizable. The calcite occurs in various sizes of crystals in colors ranging from grayish white to deep black.

MINING

Physical Characteristics of Ores and Enclosing Rocks

The physical characteristics of the wall rocks and of the ore in the upper levels of the Ash Peak mine are well suited to shrinkage stoping. Below the 800-foot level the presence of excessive water may cause a chang to a cut-and-fill method owing to sloughing of hanging-wall gouges and the diabase.

The vein is narrow, tabular, and nearly vertical; the walls are silicified andesite that stand well unsupported. The footwall of the ore body is an economic rather than a structural one. The hanging wall is kept within the limit of the ore to prevent dilution by the diabase. Drawing of ore in stopes must be done evenly to prevent piping through of the diabase, which sloughs to some extent in the partly emptied stopes.

Ore shoots are fairly continuous and consistent in grade. The hard, dense ore is difficult to drill, but it breaks into small fragments requiring no secondary blasting in stopes. In the relatively dry upper leve of the mine, broken ore flows readily from closely spaced chutes.

Prospecting and Exploration

Exploration comprises drifting on the vein and at intervals determining its width by crosscutting for short distances into the hanging and foot walls. The drifts and crosscuts are sampled by the usual methods; however, close sampling is not required, as the ore is uniform and easily identified.

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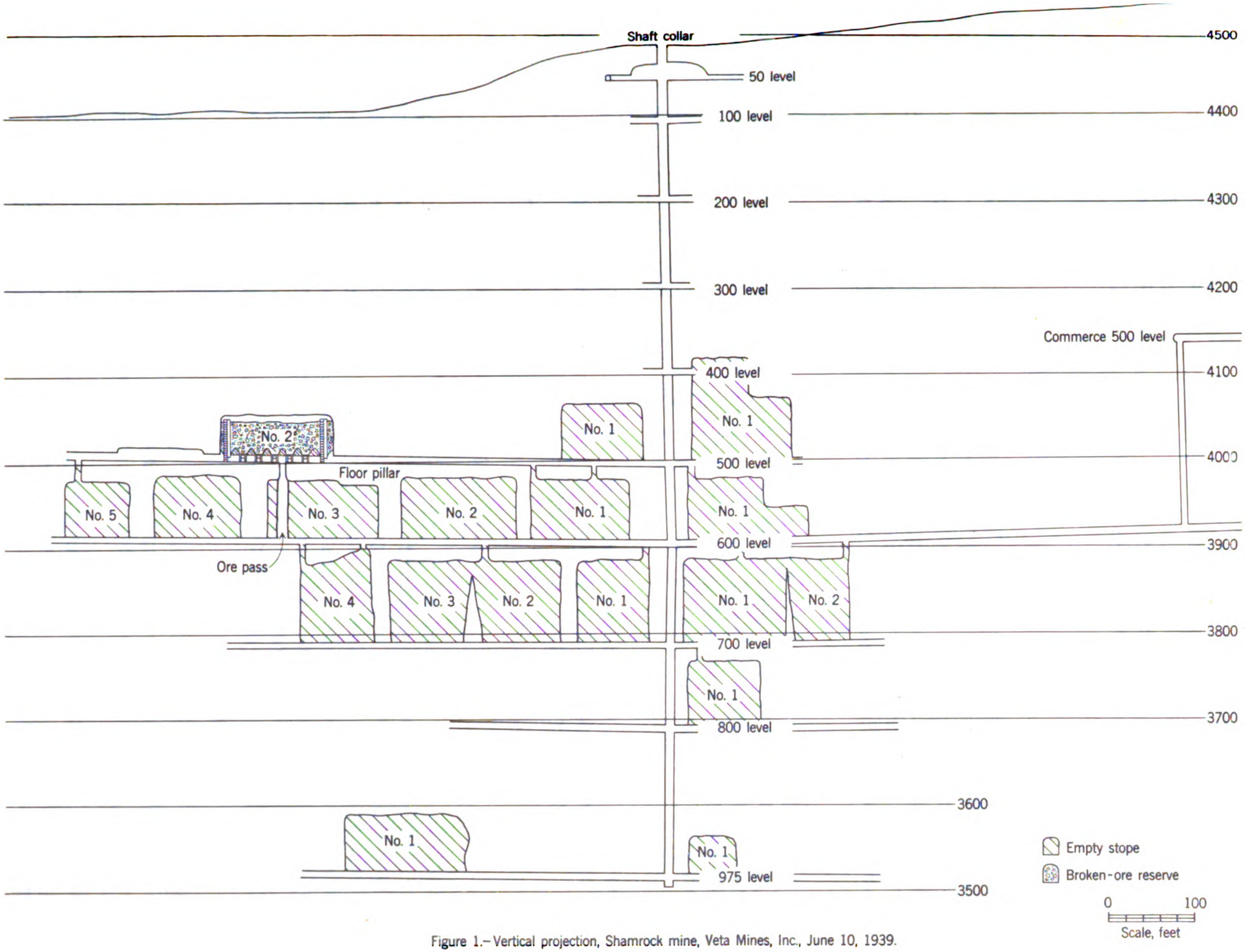


Figure 1.–Vertical projection, Shamrock mine, Veta Mines, Inc., June 10, 1939.

Some prospecting is done by diamond drilling. Three thousand feet of diamond core drilling was done during 1938 at a cost of $1.89 a foot, and from January to June 1938, 868.0 feet of diamond core-drilling was done, at a total cost of $1,582.16, or $1.82 a foot. At present (1939) all diamond drilling is contracted for at a rate of $1.25 a foot for holes up to 150 feet deep and $2.50 a foot for holes over 150 feet deep. A 5/8-inch core is recovered in shallow holes and a 7/8-inch core is obtained from the deeper holes.

Development

Figure 1 shows a vertical projection of development workings at the Shamrock mine. There are two groups of workings from which ore is mined, the Shamrock and the Commerce; the shafts are 2,000 feet apart on the surface. The 600 level of the Shamrock is connected to the 500 level of the Commerce to provide ventilation and outlets to the surface. The Shamrock has supplied about 75 percent of the ore and has been developed most extensively.

Entry to the Shamrock workings is by means of an 80° incline shaft in the vein footwall. The shaft is 975 feet deep; and the 10 levels, connected to the shaft by short crosscuts, are at 100-foot intervals, except for the 50 and 975 levels. The drifts driven on the vein for exploration are used as haulage levels. The present company has done most of its development on the 500, 600, and 700 levels.

The Commerce workings are opened by a two-compartment shaft 575 feet deep. The shaft is on an 80° incline in the footwall of the vein. The level interval is 100 feet, and crosscutting and drifting practice is similar to that in the Shamrock.

Development details

Shafts. - The Shamrock shaft is 9 feet, 6 inches, by 4 feet, 6 inches, in cross section inside the lining. It has three compartments, a 4-foot hoisting compartment, a 2-foot, 1-inch manway, and a 1-foot, 5-inch pipeway. The shaft is timbered with 6- by 8-inch Douglas fir sets throughout most of its depth. Where sets are not necessary, stulls of the same size are used. Lining is of 2- by 12-inch Douglas fir. Between compartments are full partitions of 2- by 12-inch Douglas fir hung on 4- by 6-inch fir dividers of the same. Manway landings are 18 feet apart, and ladders are staggered to conform to safety regulations.

The pipeway carries a 3-inch air line, a 1-inch water line, a water column, and electric conduits. The water line and a 2-inch air line extend to the various levels. Telephones are provided at each station.

The Commerce shaft has a hoisting compartment and a manway; the latter also serves as a pipeway. The full partition of 2- by 12-inch Douglas fir is hung on 6- by 8-inch stulls. The shaft is lined only where necessary. Hoisting is by bucket riding on skids.

Drifts and crosscuts. - The drifts driven in the vein along the footwall for exploration purposes also serve for development and ore extractio the vein having no sharp turns. Most of the drifts are 5 by 7 feet in cros section. No support is required, as there is little pressure from the wall or back.

One-hundred-and-twenty-five-pound and 145-pound drifters mounted on 3-inch columns are used for drilling. Drill steel of 1-1/8-inch, round stock with lugged shank is hand sharpened. As loss of gage is excessive in drilling the abrasive silicified andesite, the steel is sharpened with 1/4-inch changes in gage. Starting bits have a gage of 2-3/8 inches and finishing bits a gage of 1-3/4 inches. Generally, a complete change is required for each 6-foot hole, using 18-inch changes. Detachable bits were tried bu were unsuccessful because of the quick loss in gage. Used bits are ground to 1-3/4-inch gage and used with jack rods on the last change of drill stee for finishing up a hole. The purpose of this practice is to use up the supply of detachable bits on hand.

The average advance for a drift round is 4 feet. A standard round is not used as the holes are placed to take advantage of conditions at the face Generally 18 to 20 holes are drilled and about 75 1-1/8-inch cartridges of 40-percent gelatin dynamite loaded for each round. All blasting is done at the end of the night shift.

Broken rock is loaded into cars by hand, except on the 500 level, where a mechanical loader is used in widening the drift in preparation for stoping Tramming is done by hand.

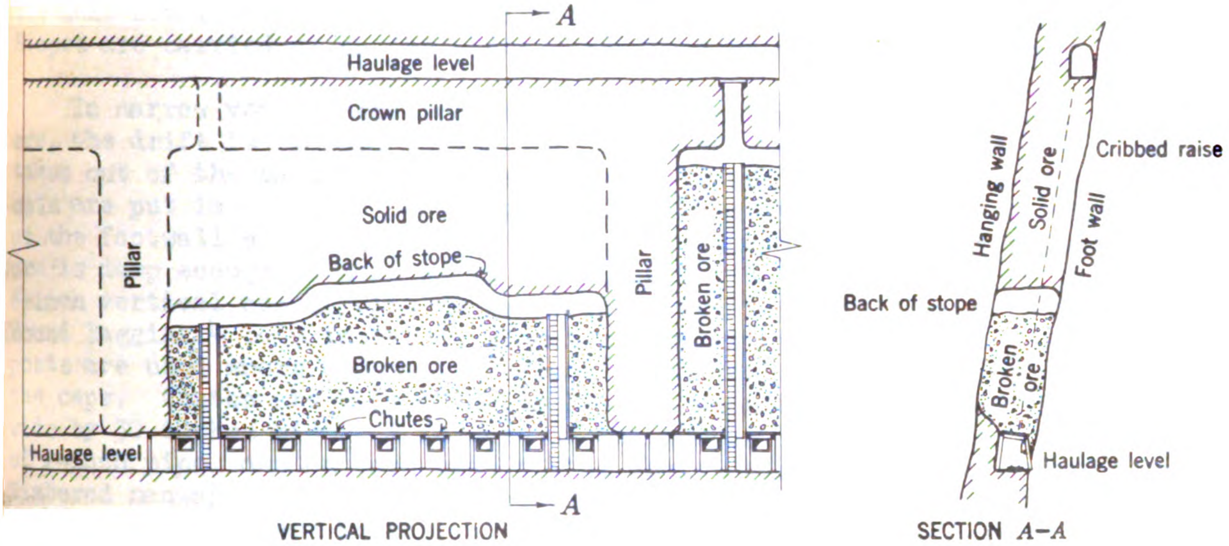
Most drifts are driven on contract at $8.00 a foot with a four-man crew comprising a machineman and helper on one shift and two muckers on the opposite shift. The company supplies tools and compressed air.

Raises. - A raise was put up to connect the 600 level of the Shamrock workings to the 500 level of the Commerce workings. Short finger raises are put up to an undercutting level in beginning some stopes, but no raises are extended ahead of stoping.

Stoping

Ore is mined by shrinkage stoping. Stoping was begun in March 1937. In June 1939 ore was being drawn from two stopes on the Shamrock at the rate of 130 to 140 tons daily; one of the stopes was being drawn empty, while the swell was being drawn from the other. About 60 tons a day was being mined from the Commerce. A third stope filled with broken ore was held in reserve.

Formerly most of the ore was stoped on timbered-drift backs; the present practice is to stope on arch pillars, particularly in the wider ore bodies. Figure 2 illustrates the two practices. Maintenance and repair costs were found to be higher when stoping was done on timbered-drift backs in wide ore shoots with a bad hanging wall than on arched pillar backs.



SHRINKAGE STOPING ON TIMBER-DRIFT BACK

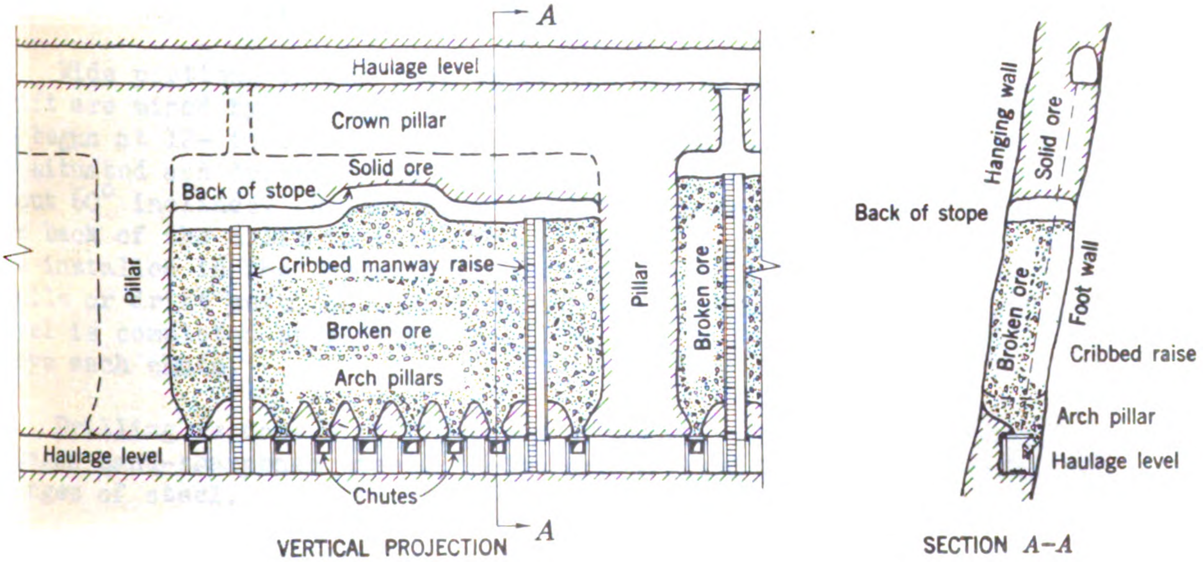


Figure 2.– Shrinkage stoping on arched-pillar back.

Stopes range in length from 100 to 130 feet. Pillars 10 to 20 feet thick, depending on the condition of the hanging wall, are left between stopes. Crown pillars 20 feet thick are left to support the haulageway on the next level above. No provision has been made to mine these pillars. Stopes are carried up on the width determined by sampling to be ore.

In narrow veins where the back of the development drift is in good ore, the drift is slabbed to the full width of the ore, and then a cut is taken out of the back. After the broken material is cleaned out, drift sets are put in on 4- to 5-foot centers, with chutes on 12- to 15-foot centers on the footwall side. The close spacing of chutes is necessary because the ore is damp enough to hang up in drawing. Drift sets are made up of 8- by 8-inch vertical posts, with 8- by 10-inch caps 8-1/2 feet above the track. Round lagging 4 to 5 inches in diameter supports the broken ore. Double posts are used where necessary. Plank spreaders are used instead of dapping the caps. Chutes are made of 3- by 12-inch material, and gates are 36 inches wide by 30 inches high. A feature of the chutes is the use of two lengths of 2-inch pipe, one on each side of the chute gates, to hold the gate boards. Timbered manways are carried up at each end of the stope along with stoping. These are 5 by 5 feet inside and have two compartments, one a manway and the other a timber slide. In wide stopes the manways are cribbed with 3- by 12-inch timber, and in narrow stopes stulls are used. A tight partition separates compartments in both types. There are 18-foot landings in the manways with staggered ladders.

To keep mining costs at a minimum, raises are not driven to the level above until the stope is nearly completed. This practice is permissible as the rock temperature is not high and natural ventilation is good.

Wide portions of the vein where the ore is lean above the back of the drift are mined by stoping on arch pillar backs. A pair of finger raises is begun at 12- to 15-foot intervals along the drift where the chutes are to be situated and driven in opposite directions in the plane of the vein on about 60° inclines. Raises from adjoining chutes intersect 15 feet above the back of the drift to form arch pillars for supporting broken ore. Chutes are installed in the footwall side of the stope on 6- by 8-inch vertical stulls or drift sets, depending on the width of the vein. The undercutting level is completed by slabbing down the ore in the V-shaped part of the stope above each chute.

Drilling is done with 120-pound automatic stopers, using 1-inch quarter-octagon hand-sharpened steel. Holes are drilled 7 feet deep, using 16-inch changes of steel.

The stope is advanced by taking a V-cut out of the center and then taking vertical slices advancing first toward one end of the stope and then toward the other. The miners stand on the broken ore to drill, and enough is drawn after each blast to leave 7 feet of headroom between the broken ore and the back. The rock breaks into small pieces, and no blockholing or bulldozing is necessary in the stopes. In 1938, 2.45 pounds of powder was consumed per ton of ore broken.

Stoping is contracted to a crew of eight men, four working on each of the two shifts. The usual arrangement is for a machineman and his helper and a timberman and his helper to work on one shift, and for another machineman and his helper and two trammers to work on the opposite shift. The day drilling-crew leaves the drill set up at the end of the shift; and the night drilling-crew completes the round, takes down the equipment, and loads and blasts the holes.

Depending on the tramming distance, the contract price for stoping is 80 to 90 cents a ton of 12 cubic feet measured in place. The contractors do all the drilling, carry up the manways, and tram all the swell. They also furnish their own explosives and pay their own compensation insurance.

All blasting is done at the end of the night shift, about midnight. From 30 to 60 holes are blasted in each stope, using 1-1/8-inch 40-percent gelatin dynamite. Air valves are left open to clear the stopes of fumes.

Underground Transportation

All tramming is done by hand with 16-cubic-foot cars, running on 18-inch gage track of 12-pound rails. The broken ore is drawn from the stopes and trammed to 25-ton ore pockets at the shaft. In 1938 the average tramming distance was 300 feet and in 1939, 500 feet. In the Shamrock workings, the ore pockets are situated on the 600,700, and 975 levels. Ore drawn on the 500 level is trammed to an ore pass in No. 3 stope and dropped through to the 600 level. Grizzlies made of 4-inch-diameter stamp stems spaced with a clear opening of 6 inches are situated over the pockets. One man for each two trammers breaks the oversize with a 16-pound hammer.

Ore is loaded into a 1-1/2-ton skip through air-operated gates and hoisted to the surface, where it is dumped automatically onto the pan conveyo leading to the coarse-ore bin. The skip serves all underground activity, including hoisting of men, supplies, and equipment. There is one skip tender on each shift to load the ore from the ore pockets, handle the supplies, and in general attend to proper operation of the skip.

Ore at the Commerce workings is hoisted in a bucket of 1,600 pounds capacity and dumped into a bin on the surface. It is loaded by gravity into a 4-ton truck and hauled one-half mile to the coarse-ore bin at the crushing plant. Truck haulage is done on contract at the rate of $0.20 a ton.

Percentage of Extraction

Nearly all the ore broken is recovered with little dilution in grade if the stopes are drawn completely empty in one operation and drawing is done evenly. No waste is sorted, either underground or on the surface. Where development or other workings are driven in country rock the broken material is loaded as waste and dumped into empty stopes if possible.

The total extraction of ore is about 85 percent where stoping is done on timbered-drift backs and about 75 percent where stoping is done on arched pillar backs.

Drainage

Underground water at the Shamrock workings is intercepted on the lower levels and collected in the shaft sump. About 30,000 gallons a day is collected under normal conditions. A duplex reciprocating pump with a capacity of 250 gallons a minute, driven by a 40-horsepower motor, handles the excess water in about 2 hours each shift.

Ventilation

A connection between the 600 level of the Shamrock workings and the 500 level of the Commerce workings provides good natural ventilation for both. Dead-end drifts are ventilated by means of electrically driven auxiliary blowers. The air is directed to the face through 8-inch canvas ventube. Raises and stopes are cleared by opening the compressed-air valves before blasting at the end of the night shift.

Mine Labor

As much of the mining as practicable is done on contract. It has been found that this practice attracts the best class of miners to the camp. The contractor pays compensation insurance and pays for his explosives. Contracts are made at the following rates:

Drifts, 5 by 7 feet in section..............	$ 8.00 per foot
Drifts, 7 by 9 feet in section..............	11.00 per foot
Raises, the company doing all loading and ore-drawing..................................	6.00 per foot
Timbering for stope preparation............	25.00 per chute
Timbering straight back stopes.............	2.00 per foot
Stopes - $0.60 to $0.80 per measured ton of 12 cubic feet. The $0.80 contract rate is made to a crew of 8 men, who do all breaking, tramming of swell, and timbering of manways.	
Tramming from stope and ore pass............	0.30 per ton

Surface workmen and part of the men working underground are on straight company time. Two 8-hour shifts are worked for 6 days a week. Time is figured on the basis of a 6-hour shift, with the two extra hours as overtime at one and a half times the hourly rate.

The number of man-hours worked during 1938 in mine leasing, exploration, development, and ore extraction follows:

Breaking -	15,275
Timbering -	12,580
Tramming and loading -	40,450
Total	68,305

The following table shows the average distribution of employees in June, 1938, in the mine and on the surface, including the mill.

Average distribution of employees in June 1938 in the mine and on the surface, including the mill

Shamrock Mine	
Underground	23
Surface, including hoisting	3
Commerce Mine	
Underground	9
Surface (hoisting)	2
General	
Diamond drilling	1
Mill (including crusher)	8
Powerhouse	4
Shops (including steel sharpening	7
Warehouse	1
Assaying	1
Superintendence	2
Engineering	1
Truck transportation	3
Tailings dam	1
Water supply	3
Daily average for June	69

The wage rates in effect in June 1939 are shown in the following table:

Classification	Rate per 8-hour shift	Hourly rate for 6 hours	Hourly rate for overtime
Surface labor	$ 3.50	$ 0.38	$ 0.61
	3.60	.39	.63
	4.00	.44	.68
Muckers, trammers, and mill helpers	4.05	.44	.705
Hoistmen	4.28	.46	.76
Miners and timbermen	4.50	.48	.81

Safety, First Aid, and Fire Protection

The regulations set forth in the Arizona State Code of Mining Safety are observed and practiced. All manways have staggered ladders with landings, and full partitions are installed between the manways and timber slides.

As a means of promoting safety and efficiency, electric cap lamps are used for individual illumination underground. Sixty lamps are available for renting to the employees at $1.00 a month, which takes care of charging, maintenance, and repairs. The greatest repair items are lenses and globes. Lamps are checked out at the beginning and checked in at the end of each shift. A special room off the change house is provided for storage and charging of the lamps. The capacity of the charger is 50 lamps each 6 hours. A surface employee is responsible for proper maintenance of the lamps; he also cleans up the change room, makes primers, and trams the waste hoisted.

No trained first-aid teams have been developed up to the present, but many of the miners have had first-aid instruction.

There is little danger of fire underground because of the natural dampness. The connection between the Shamrock and Commerce workings provides an exit in case of fire. Water is available from taps into the waterlines at intervals on the levels. Two fire-fighting helmets are part of the standard mine equipment.

The housing of surface equipment is in nearly all instances wood framework covered with corrugated-steel sheeting. Dwellings, the office building, and the dining room and commissary building are the chief fire hazards, as they are of wood finished with stucco.

Mining Costs

Direct stoping costs per ton mined and milled, in units of labor, lumber and timber, power, water, explosives, and other supplies, are shown in the following table for 1938, when 64,709.8 tons of ore was mined and milled at the Ash Peak mine.

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Direct stoping costs per ton mined and milled in units of labor, explosives, lumber and timber, power, water, and other supplies for 1938

	Cost per ton mined and milled
Labor	$ 1.1174
Explosives	.2042
Lumber and timber	.0978
Power	.1179[1/]
Water	.0075[1/]
Other supplies	.1439
Miscellaneous	.1749
Total stoping cost per ton mined and milled	$1.8636
Total operating cost, 1938, per ton mined and milled	$ 4.9394[2/]
Percent stoping cost of total cost	37.7 percent

[1/] Percentage of total consumption estimated.

[2/] Includes leasing, exploration, development, ore crushing and milling, handling and hauling concentrates, administration, and overhead per dry ton mined and milled (see "Combined Costs" p. .)

The cost of development work from January to June 1938, inclusive, was $16,665.36 for 1,038.8 feet of drifting, crosscutting, and raising, or $16.04 a foot. The cost of development work for the entire year 1938 was $15.94 a foot; the cost per ton mined and milled was $0.26.

The cost of principal mine supplies follows:

Explosives:	
40-percent gelatin dynamite, 1-1/8 by 8-inch cartridges, per 100 pounds, delivered	$ 11.75
Timber:	
Native, sawed, per 1,000 board feet	28.00
Douglas fir, not sawed:	
Stulls, 12-inch diameter small end, per foot delivered	.12
Stulls, 8-inch diameter small end, per foot delivered	.10
Stulls, 6-inch diameter small end, per foot delivered	.08

MILLING

The crushing plant and mill are situated at the mine near the Shamrock shaft. Gravity flow is used in the design, except that the ore discharged from the crushing plant is elevated by conveyor to the fine-ore bin.

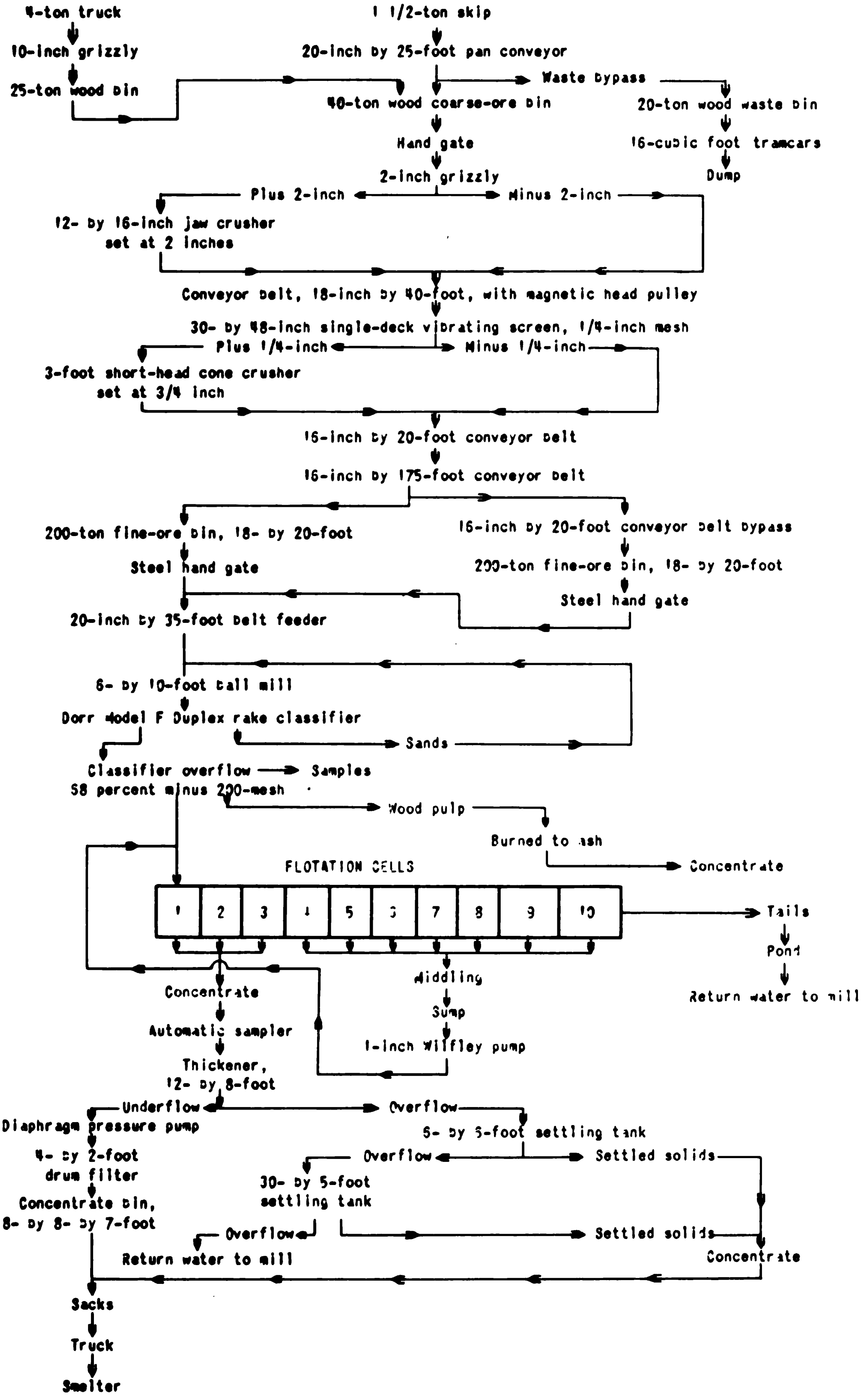

Figure 3.- Flow sheet of Ash Peak mill of the Vega Mines, Inc.; capacity, 190 tons.

The buildings housing the crushing plant and mill are of conventional wood-frame construction covered with corrugated-iron sheeting. Milling operations were begun in March 1937. In June 1939, about 190 tons of ore was being treated daily by flotation, producing 1.7 tons of silver concentrate.

The combined flow sheet of the crushing plant and mill is shown in figure 3.

Crushing and Grinding

Ore from the Shamrock is delivered to the crushing plant by a 1-1/2-ton self-dumping skip. The skip discharges into a trough loading a 20-inch pan conveyor, which carries the ore up a 25 foot, 10-percent slope to a 40-ton, wood coarse-ore bin. Waste can be by-passed from the discharge end of the pan conveyor to a 20-ton, wood waste bin, from which it is loaded by a hand-operated chute into a 16-cubic-foot car and trammed by hand to a waste dump. A 25-ton wood bin beside the main coarse-ore bin has a common opening with it. Trucks hauling ore from the Commerce shaft dump through a grizzly with 10-inch spacings into this bin. The grizzly bars are old stamp stems, 3-1/2 to 4 inches in diameter. Oversize is broken manually.

The coarse ore is discharged through a hand-operated gate onto an inclined grizzly with 2-inch spacings which by-passes undersize, the oversize being fed into a 12- by 16-inch Buchanan jaw crusher driven by a 25-horsepower motor. The discharge is set at 2 inches, but the majority of the crushed product is 3/4 inch in size. The crusher jaw plates are of manganese steel. They are changed each week and the worn ones built up by welding on a hard-facing metal. The ore is very abrasive.

The crushed ore and grizzly undersize discharge onto an 18-inch conveyor belt 40 feet long, running up a 20-percent incline. It is driven by a 2-horsepower motor, at a belt speed of 150 feet per minute. The magnetic head pulley picks tramp iron from the circuit. The conveyor discharges onto a 30- by 48-inch single-deck vibrating screen with 1/4-inch openings, driven by a 2-horsepower motor. The oversize from the screen discharges into a 3-foot, short-head, Symons cone crusher driven by a 60-horsepower motor. The crusher is set at 3/4 inch, but the majority of the product is about 1/4 inch in size. Liners last about 6 weeks. The discharge from the crusher and the undersize from the screen drop onto a 16-inch horizontal conveyor belt 20 feet long, driven by a 1-1/2 horsepower motor, which discharges onto a 16-inch crossbelt driven by a 5-horsepower motor. The second belt conveys the ore up a 30-percent incline 175 feet to the fine-ore bins. A flap of discarded rubber belting is arranged near the loading end of the second conveyor belt to close an electric circuit and sound an alarm if there is no ore on the belt. A similar arrangement is placed on the feed end of the Symons crusher to sound a warning if the crusher becomes choked with feed.

Two 18- by 20-foot, 200-ton fine-ore bins are situated side by side at the head of the mill building. The 175-foot conveyor discharges directly into one of these bins and by-passes to the other bin by a 16-inch conveyor belt 20 feet long, driven by a chain from the 175-foot conveyor. The by-pass conveyor is supported by a framework mounted on four car wheels running on 30-inch-gage tracks of 16-pound rail. The auxiliary conveyor is moved over by hand to by-pass the ore stream into the second bin when the first is full. Both bins are filled by Saturday night, as the mine is not worked Sundays. The crushing plant operates about 12 hours a day.

Ore discharges from the fine-ore bins onto a continuous flat feeder belt, 20 inches by 35 feet in length, driven by a 5-horsepower variable-speed motor. Discharge is regulated through steel gates arranged in tandem, so that ore can be fed from either or both bins. A flap arrangement of the type described sounds a signal electrically when the belt feeder is empty.

Crushed ore discharges into the feed box of a 6- by 10-foot Stearns-Roger ball mill, driven by a 200-horsepower synchronous motor at 24 r.p.m. and loaded with 30,000 pounds of 3-inch forged-steel balls. Manganese-steel liner consumption is about 0.7 pound and ball consumption 4.2 pounds per ton of ore. Cast-iron balls were tried, but their use was discontinued when it was found that consumption was more than double that of forged-steel balls.

The pulp from the ball mill discharges at 72 percent solids through the trunnion to a Dorr Duplex classifier, Model F, 6 by 24 feet, 3 inches, driven by a 5-horsepower motor. The classifier is in closed circuit with the ball mill. A circulating load of about 800 percent is maintained.

A unit flotation cell was placed in the grinding circuit between the discharge end of the ball mill and the classifier in an attempt to improve recovery. Its use was found to be not applicable to this ore.

The approximate distribution of sizes in the classifier overflow follows:

	Percent
Plus 100 mesh	4
Minus 100 plus 150 mesh	12
Minus 150 plus 200 mesh	16
Minus 200 mesh	68
Total	100

Chips and pulped wood caught on the overflow screen of the classifier are collected and burned periodically. The ash, containing about 80 ounces of silver and 1/2 ounce of gold per ton, is screened, sacked, and shipped to the smelter.

Flotation

The classifier overflow passes into the No. 1 cell of a 21-inch, 10-cell Stearns-Rogers flotation machine of the Minerals Separation type. The impeller of each cell is driven by a 5-horsepower motor. A finished concentrate is taken from the first three cells, which are in series. The tailing from these cells is fed to No. 4 cell. The middling concentrate taken from the seven remaining cells, which are in series, is returned by means of a 1-inch Wilfley pump driven by a 3-horsepower motor to the feed into No. 1 cell. Positive aeration is furnished at 2-1/2 pounds pressure by a No. 615 Acme blower driven by a 3-horsepower motor. The pulp density in flotation is low, being only 18 to 19 percent solids. An automatic sampler cuts the concentrate stream from the flotation machine at 15-minute intervals to give a composite sample of the mill operation for each shift.

Reagents are fed to the ball mill, to the classifier overflow, and to the fifth cell of the flotation unit. A two-compartment wet reagent feeder of the disc and-cup type, driven by a 1-horsepower motor through a speed reducer, feeds 0.07 to 0.08 pound of Barrett No. 4 and 0.3 pound of pine oil to the discharge end of the belt feeder. A reagent made up of half pentasol xanthate and half ethyl xanthate is fed at a rate of 0.083 pound for each ton of ore into the feed box of the ball mill from one compartment of a three-compartment wet reagent feeder of the disc and-cup type. The other two compartments feed the same amount of the reagent to the classifier overflow and to No. 5 flotation cell, respectively. The feeder is driven from the classifier drive shaft.

Tailings Disposal and Handling of Concentrate

The tailings from flotation flow by gravity to the tailings pond in a nearby gulch. Tailings are impounded to conserve water, which is returned to the mill circuit.

The concentrate from flotation is washed into a 12- by 8-foot Dorr thickener. The rakes are driven by a 3-horsepower motor at a speed of 1/6 r.p.m. Copper sulfate is fed to the thickener as a settling agent at the rate of 0.03 pound per ton of original feed.

Overflow from the thickener contains 2 to 3 percent solids; it flows by gravity to a 6- by 6-foot steel settling tank and from there to a larger steel 30- by 5-foot settling tank. The overflow from this last tank is returned to the mill circuit. The settled solids are cleaned out of the large tank every 60 days and sacked as concentrate; about 900 sacks is recovered at each clean-up. This material contains about 300 ounces of silver per ton of concentrate. The small tank is pumped out weekly.

The underflow from the thickener at 50 percent solids is pumped by a 2-inch Door pressure diaphragm pump driven by a 3-horsepower motor to a 4- by 2-foot Door drum filter. This filter is driven by a 1-horsepower motor. A 7-1/2 by 6-inch Chicago Pneumatic vacuum pump driven by a 5-

horsepower motor maintains a vacuum of 20 inches of mercury. The cake is blown off the drum by air from the same blower that furnishes air for flotation and falls into sacks hung on racks for the purpose. Filled sacks are stored in the concentrate room. Filtrate is pumped from the receiver back into the mill circuit by a 1-1/2-inch centrifugal pump driven by a 2-horsepower motor.

A 1-inch centrifugal pump driven by a 1-horsepower motor returns waste water collected in the sump.

Metallurgical data

An analysis of the typical mill heads follows:

Ag	ounces per ton	10.97
Ag as chloride and bromide	do	.30
Au	do	.025
SiO_2	percent	85.8
Sulfur	do	.045
Fe_2O_3	do	3.21
Al_2O_3	do	3.28
CaO	do	5.07
Mn	do	.45
Moisture	do	2.1

An anlysis of the average concentrate follows:

Gold	ounces per ton	1.50
Silver	do	550.50
Lead	percent	.3
Copper	do	.18
Zinc	do	.5
Sulfur	do	.3
Alumina	do	1.5
Silica	do	75.4
Iron	do	6.3
Undetermined	do	13.22

The moisture content of the concentrate just after filtering is about 25 percent. During shipment to the smelter the content is reduced to an average of 18 percent.

The ratio of concentration is 110 to 1 and about 65 percent of the silver is recovered. Tests indicate that the recovery of silver can be raised somewhat by finer grinding, but such practice raises grinding costs excessively. The recovery by cyaniding the crude ore or by cyaniding the tailings could be raised to only 80 percent. Efforts to improve recovery by using different amounts and other types of reagents have failed.

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Mill Control

An automatic sampler for mill heads was installed with the mill as originally built, but later was discarded. Samples are now taken by hand at the classifier overflow and automatically from the concentrate discharged from flotation.

There is a small metallurgical testing laboratory in the mill. Equipment includes a batch ball mill, laboratory flotation cell, electric hot plates and drying ovens, and an analytical balance.

The mill operator on each shift makes a daily report of the operation of the mill. The form of this report, filled in to show the actual operation on the day shift on June 9, 1939, is shown in the following table.

Form of daily report, showing operation of mill.

Date: 6/9/39 Shift: Day.

Time	Feed	Percent solids		Reagents, c. c. per minute					
		1/ C. O.	2/ B. M.	Z-6 and Z-3 B. M.	Z-6 and Z-3 C. O.	Z-6 and Z-3 No. 5 cell	Barrett B. M.	P. O. B. M.	P. O. C. O.
8	280	19	72	54	50	44	5	8	2
9	276	18	71						
10	276	19	72	54	50	50	5	8	3
11	272	19	72						
12	280	19	73	50	52	54	5	8	3
1	276	18	72						
2	276	18	73	52	54	54	5	8	4
3	276	19	70						
	2,212								

1/ Classifier overflow. 2/ Ball-mill discharge.

Average percent solids:

Wet tons: 66.4
Percent moisture: 2.8
Dry tons: 64.5
Hours run: 8

Concentrate in store: 22
Concentrate sacked: 13
Total sacks: 35

Remarks:

Marketing Concentrate

Concentrates are hauled by truck in 225-sack lots of about 6 tons by way of Lordsburg, N. Mex., to the American Smelting & Refining Co. lead smelter at El Paso, Tex. The freight rate is $6.00 a ton for the distance of 215 miles, making the cost per ton-mile $0.028.

Settlement was made at the following rates in June 1939:

Silver, 97.50 percent of domestic price of 64.64 cents per ounce for concentrate assaying 500 ounces or more of silver per ton; 95.00 percent of domestic price for concentrate assaying less than 500 ounces of silver per ton.
Gold, $32.81 per ounce.

The company attempts to hold the grade of concentrate above 500 ounces of silver per ton.

Deductions were as follows (June 1939):

	Per ton
Base charge........................	$ 5.09
Handling sacks.....................	.50
Sampling charge, including assaying, $6.00 for each truck-lot of about 6 tons...........................	1.00
Total..........................	$ 6.59

Where an appreciable difference exists between mining company and smelter assays, a sample is taken by representatives of both companies and submitted to an umpire for analysis; the cost of this work is borne by the party whose results are greatest in error.

Until early in 1938 crude ore was shipped to the International Smelting & Refining Co. at Miami, Ariz. Shipments were made by truck to Solomonville, Ariz. The freight cost to this point (24 miles from the mine) was $1.25 per ton. The smelter paid the freight from Solomonville to Miami. The base charge was $3.25 a ton, and there were no penalties. Settlement was made at the following rates:

Silver, all at 95 percent of domestic quotation.
Gold, $32.20 an ounce.

Mill labor

The mill operates three shifts daily for 7 days a week. The following table shows the labor and supervision required to treat 190 tons daily:

Number	Classification	Rate	Total per day
3	Mill operators	$4.50	$13.50
3	Mill helpers	4.05	12.15
2	Crusher men	4.50	9.00
1	Superintendent	6.00	6.00
			$40.65

Mill supply costs

The costs of the principal mill supplies follow:

Item	Cost 1/
Reagents:	
Pine oil.........................	$0.079 per pound
Potassium ethyl xanthate.........	.140 per pound
Potassium pentasol xanthate......	.275 per pound
Barrett No. 4....................	.075 per pound
Copper sulfate...................	.819 per pound
Lubricating oil..................	.62 per gal.
Manganese-steel crusher-jaw plates	105.00 per set
Manganese-steel cone-crusher liners	380.00 per set
Manganese-steel ball-mill liners...	.125 per pound
Forged-steel balls...............	80.00 per ton
Flotation impellers..............	31.00 each

1/ Delivered to mine.

The costs of grinding balls, mill liners, and reagents per ton of ore milled for 30 days in May 1939 is shown in the following table.

Item	Total Cost	Ore milled tons	Cost per ton ore milled
Grinding balls	$970.05	5,295	$ 0.1832
Mill liners	750.00	5,295	.1416
Reagents	510.00	5,295	.0963

POWER

Electric power for the mine and mill is generated on the property. The power plant is near the mill and is housed in a frame building covered with corrugated-steel sheeting. Equipment includes four Union Diesel engines of 250 horsepower capacity each, direct connected to 250-kv. a. alternators of which one unit is a spare.

Electricity is furnished at four different voltages - 2,300 volts for the crusher and ball-mill motors, 440 volts for all other motors rated more than 1 horsepower, 220 volts for large-wattage lamps, and 110 volts for general lighting circuit and fractional horsepower motors. Power distribution is as follows:

	Percent
Mine	57
Mill, of which 20 percent is used in coarse crushing	40
Camp	3
Total	100

Stations and main levels in the mine are lighted electrically. Electric lighting for the mill is provided from ceiling and drop-cord lamps. The automatic sampler is operated from the 110-volt circuit also.

The connected power load for the mill follows:

Motor	Voltage	Horsepower
Ball mill	2,300	200
Ore feeder	440	5
Reagent feeder	440	1
Reagent feeder	440	5
Classifier	440	5
Flotation cells, 5 horsepower on each	440	50
Blower	440	5
Wilfley pump	440	3
Filtrate pump	440	2
Vacuum pump	440	5
Thickener	440	3
Diaphragm	440	3
Filter	440	1
Sump pump	440	1
Total		289

Five men are required to operate the plant on three shifts. Labor cost, including supervision, is $22.50 a day. The cost of Diesel fuel, the principal item of supply, is $0.0625 per gallon delivered to the mine. The cost of operation for 1938 on the basis of 64,709.8 dry tons milled is shown in the following table.

Cost of operating power plant for 1938
in units of labor, supplies, and lumber.

Labor	$ 0.1603
Supplies	.2983
Timber	.0001
Total operating cost	$ 0.4587
Operating income	.0011
Total cost per ton milled	$ 0.4576

Outlying workings have independent power plants.

WATER SUPPLY

All the water supply is pumped from a well at Ash Springs sunk 5 feet by 5 feet in section a depth of 80 feet. A duplex reciprocating pump, driven by a 40-horsepower tractor Diesel engine, delivers the water through 7,000 feet of 3-inch pipe up a rise in elevation of 1,400 feet to a steel tank 30 feet in diameter by 12 feet in height.

The water for the mill is stored in two steel tanks 30 feet in diameter by 10 feet in height situated just above the mill. These act as surge tanks for water returned from the tailings pond. Additional water is drawn from the main supply tank as needed. The mill uses about 5 tons of water per ton of ore; about 50 percent is reclaimed.

An evaporative tower with a capacity of 3,000 gallons a day cools water for the Diesel engines and compressors.

Distribution of the total daily water consumption of 325,000 gallons follows:

	Percent
Mill	80
Mine	18
Camp	2
Total	100

The cost of supplying water for 1938 on the basis of 64,709.8 dry tons of ore milled is shown in the following table.

Cost per ton of ore milled of supplying water for 1938 in units of labor, supplies, and lumber

Labor	$0.0445
Supplies	.0416
Lumber	.0007
Miscellaneous	.0056
Total cost per ton milled	$0.0924

SURFACE PLANT

The surface plant is arranged to provide all the ordinary services required to keep the mine and mill in good operating condition. Buildings are mostly of wood frame construction covered with corrugated-steel sheeting. Besides the power plant already mentioned, the surface plant comprises the Shamrock shaft house, the Commerce shaft house, a machine shop, an electric shop, a change house, a warehouse, an assay office, and the administration office.

At the Shamrock shaft hoisting is done from a 60-foot steel head frame with a 6-foot-diameter drum hoist, driven by a 100-horsepower electric motor at a rope speed of 450 feet per minute. At the Commerce shaft hoisting is done with a 30-inch-diameter drum hoist driven by an automobile engine. The hoisted ore is dropped into a wood ore bin adjacent to the 30-foot wood head frame. Compressed air is supplied by a 400-cubic-foot-per-minute compressor driven by a 60-horsepower tractor Diesel engine.

Compressed air is supplied to the Shamrock workings by a 640-cubic-foot-per-minute compressor driven by a 100-horsepower electric motor and two 360-cubic-foot-per-minute compressors driven by 60-horsepower electric motors. This equipment is in the power house.

Machine-shop equipment includes a 40-volt, 200-ampere portable arc welder, a metal turning lathe with a 6-foot bed and 12-inch swing, a 21-inch drill press, a power cut-off saw, a power grinder, and a drill-steel sharpener remodeled to split diamond-drill core.

In the blacksmith shop are an air-operated drill-steel sharpener, a power grinder, a homemade oil-fired furnace, and a hand forge.

The electric shop is equipped to rewind motors and to do other electric repair work.

The change house is 20 by 40 feet in area and equipped with individual lockers and showers.

The warehouse contains supplies and replacement parts for the mining and milling equipment.

The assay office is equipped to make routine analyses by fire and wet methods for control of the mining and milling operations.

Fuel oil is stored in two steel tanks of 15,000-gallon and 5,000-gallon capacities.

LIVING ACCOMMODATIONS

Living accommodations for company employees comprise 11 four-room dwellings rented to individual families at $10 to $25 a month, two 40- by 60-foot bunkhouses with eight rooms each, and a 40- by 60-foot boarding house with dining room, kitchen, commissary, and storeroom. Board is furnished at the rate of $1.25 a day, and room in the bunkhouse at the rate of $4.00 a month.

ADMINISTRATION

Operations at the Ash Peak Branch are supervised by a general superintendent assisted by three shift bosses, and milling operations are directed by a mill superintendent. Also on the Company staff are a master mechanic, chief electrician, chemist, engineer, purchasing agent, and chief clerk.

SUMMARY OF COSTS

A summary of individual costs is shown in the following table.

Individual costs:

Exploration (diamond drilling) per foot..........	$ 1.8881
Development workings, per foot....................	15.9386
Ore extraction per dry ton mined and milled......	1.8636

Combined operating costs for 1938 and total operating costs follow:

Combined costs, per dry ton mined and milled	
Leasing, exploration, development, and ore extraction................	$ 2.6831
Coarse crushing......................	.1665
Milling, general.....................	.8074
Handling and hauling concentrate....	.0910
Administration and overhead.........	1.2342
Total cost.....................	$ 4.9822
Income from operation of camp.......	.0428
Total operating cost................	$ 4.9394

Metals production during 1938 and cost per ounce of producing silver is shown in the following table.

Gold	ounces	1,751.86
Silver	do..	527,706.45
Copper	pounds	9,389.32
Lead	do..	26,246.97

Production cost per ounce of silver, $0.60463.

A summary of operating expense per dry ton of ore mined and milled at the Ash Peak mine for 1938 is shown in the following table.

Summary of operating expense per dry ton of ore mined and milled at the Ash Peak mine in 1938.

Dry tons mined: 70,274.8
Dry tons milled: 64,709.8
Dry tons shipped direct to smelter: 5,565.0

Account	Labor	Explosives	Power	Water	Lumber and timber	Other Supplies	Miscellaneous	Total	Percent of Total
Administration overhead and general	$0.4875	--	$0.0283 1/	$0.0009 1/	$0.0006	$0.1475	$0.5694	$1.2342	25.0
Mine leasing	.1611	$0.0336	.0472 1/	.0028 1/	.0111	.0461	.0905	.3924	8.0
Mine exploration	.0296	--	.0189 1/	.0009 1/	.0002	.0139	.0070	.0705	1.4
Mine development	.1391	.0670	.0708 1/	.0046 1/	.0008	.0181	.0562	.3566	7.2
Mine-ore Extraction	1.1174	.2042	.1179 1/	.0075 1/	.0978	.1439	.1749	1.8636	37.7
Coarse crushing	.0472	--	.0377 1/	--	.0002	.0786	.0028	.1665	3.4
Milling, gen'l.	.1961	--	.1510 1/	.0739 1/	.0007	.3556	.0301	.8074	16.3
H. & H. conc.	.0206	--	--	--	--	.0042	.0662	.0910	1.8
Camp	.0058	--	.0142 2/1/	.0018 1/	.0003	.0217	.0582 2/	.0428 2/	.8 2/
Total operating	2.2044	.3048	.4576	.0924	.1117	.8296	.9389	4.9394	100.0
Percent of total	44.6	6.2	9.2	1.9	2.3	16.8	19.0		

1/ Percentage of total consumption estimated. 2/ Operating income.

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A summary of capital expense at the Ash Peak mine for 1938 follows:

Account	Labor	Explosives	Lumber	Other Supplies	Misc.	Total
Construction	$ 307.84	$ 55.03	$ 18.18	$ 183.10	$ 21.50	$ 585.65
Equipment	523.91	- -	285.96	3,078.21	4,981.06	8,869.14
Total capital	831.75	55.03	304.14	3,261.31	5,002.56	9,454.79